Unburned Carbon from Fly Ash - A Hidden Treasure

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Introduction

The Institute of Materials Processing at Michigan Technological University has developed a beneficiation technology that recovers unburned carbon from fly ash. This work was supported in part by the U.S. DOE under contract no. DE-FC21-94MC31175. The patented technology is licensed to Mineral Resources Technology (MRT) from Atlanta, Georgia. Carbon removal benefits fly ash utilization by producing a low-carbon, quality controlled fly ash, thus promoting ash use in a variety of markets, such as cement/concrete, plastics, and refractories. The recovered carbon can be used as a sorbant in applications that use activated carbon. Tests have shown recovered carbon has better sorbability than commercial activated carbon in applications such as the adsorption of mercury from flue gas streams for emission control. Other carbon uses are being developed.

Background

A fly ash beneficiation process has been developed that utilizes conventional, off-the-shelf processing equipment to recover cenospheres, magnetic material, and carbon from fly ash while producing a clean ash suitable for use in concrete and other applications. The patented, water based process incorporates gravity separation to skim off cenospheres, and magnetic separation to remove the magnetic particles. The carbon is separated from the clean ash using froth flotation. All or selected steps in the process can be performed, based on the needs of the operator and the ultimate end use of the components.

Fly ash is a byproduct of combustion and therefore is influenced by the fuel source and the combustion conditions. The purpose of the combustion is to generate electricity and combustion conditions are modified to accommodate the electrical needs. This leads to widely varying fly ash compositions. More recently, to address CAAA standards many utilities are modifying their combustion practices and fuel sources. This has a significant impact on the fly ash, often increasing the amount of carbon and trace elements present in the ash. This produces ash that can no longer be used in concrete or other existing applications, resulting in increased disposal of ash. The beneficiation process developed by MTU can remove contaminants such as carbon, barium, and other trace elements, and produce a quality controlled fly ash product for use in concrete and other higher value applications such as plastics and ceramics.

High carbon content in fly ash was the original problem to be solved. Development of the beneficiation process addressed that issue. It is possible to produce consistent, clean, quality controlled fly ash. However, there was still the carbon to deal with and the carbon turned out to have even more potential high value applications than the clean ash.

Carbon has an affinity for organic compounds which make it useful as an industrial sorbent material. It is widely used to (1) adsorb volatile organic compounds (VOCs) in air treatment, (2) remove odor, color, and organic compounds in water treatment plants and pharmaceutical and food industries, and (3) recover precious metals from solutions. Activated carbon has received increased use in recent years as a result of emphasis on pollution prevention and demands for higher purity products. Another potential application of carbon has been identified in recent exploratory research at IMP. The study showed that, without any optimization, separated fly ash carbon can remove 75% of the mercury from a simulated stack emission.

Carbonaceous materials such as coal, wood, fruit shells, etc. are the typical starting materials for producing activated carbon. Producing activated carbon from coal involves carbonization (pyrolysis) followed by steam activation, and requires extensive emission controls during the carbonization stage. The unburned carbon found in fly ash will not require such extensive environmental controls because carbonization has already taken place in the power plant burner, where emission controls are in use.

The U.S. imports significant amounts of activated carbon. This is, in part, due to the environmental costs associated with domestic processing. Success in manufacturing activated carbon from fly ash will not only reduce environmental problems associated with fly ash disposal and the conventional manufacture of activated carbon, but will also help meet the future demand for activated carbon from domestic sources.

It is possible for the beneficiation process to be economically feasible when only selling a clean ash product. But, carbon is potentially a much higher value product and will significantly enhance the economics if it is also viewed as one of the products from the beneficiation process.

Research Findings

Fly ash samples with a wide range of LOI values (from 2 to 25%) have been processed, with resulting clean ash values of 2% LOI or less and typical weight recoveries of 60% to 80% depending on the feed LOI values. To date, beneficiation efforts have focused on obtaining a clean ash stream and most ash samples tested were cleaned to < 1% LOI. Preliminary tests to determine the maximum carbon concentrate levels obtainable have resulted in carbon concentrate grades of over 80% LOI.

The carbon obtained from the beneficiation process is comprised mainly of macropores, mostly 250 to 3000 nm in diameter. A commercially available activated carbon consists primarily of micropores less than 2 nm in diameter. The BET surface area for unburned carbon varies from 20 to 60 m^2/g. A commercially available activated carbon had a surface area of 946 m^2/g. Unburned carbon has limited surface area and is predominated by macropores. Since surface area is related to adsorption capacity and macropores are important for the passage of absorbates to meso- and micro-pores, fly ash carbon is expected to have fast overall adsorption kinetics with reasonable capacity. Also, larger pores allow easier regeneration. Thus, unburned fly ash carbon may be more suitable for adsorption of medium and large molecules.

Tests showed that, compared with two commercial activated carbon samples, the carbon samples obtained from fly ash have a larger mercury adsorption capacity at low mercury concentrations, 20 to 250 micrograms per cubic meter. Utility flue gas streams can have mercury concentrations in the range of 40 to 1000 micrograms per cubic meter.

These findings show that unburned carbon from the beneficiation process has the potential capability to adsorb pollutants from gas streams.